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Physico-chemical analysis of water from the upper sector of Tigris river which passed throw Wasit province, southern Iraq

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This study investigates the physico-chemical parameters of the upper sector of the Tigris River within Wasit Province, Southern Iraq. Five sites along a 1415 Km stretch of the river were selected, and water samples were collected monthly from January to December 2022. The findings indicate variations in water parameters, revealing low salinity, weak alkalinity, good aeration, moderate pollution levels and very hard. Nitrates recorded values from 0.08-1.97 mg/L, which are less than the permission limits. The Orthophosphates recorded values from 0.009-0.064 mg/L, which is slightly higher than the standard value (0.01 mg/L) allowed for natural water. The water of Tigris River was also classified as somewhat polluted according to the standards recorded for the COD (100 mg /L). Chlorine recorded values that ranged from 98.55-216.81 mg/L, which is within the internationally permission limits of 250 mg/L. The sodium concentration was151 mg/L (the value in freshwater ranges from 1-10 mg/L and WHO 200 mg/L), so the values of the current study are within the permission limits. The results contribute valuable insights into the state of the Tigris River in the studied region.
Keywords: Chemical Analysis, Physical Analysis, Tigris River, Wasit Province, Water quality.

INTRODUCTION

The assessment of water quality through the analysis of physical and chemical properties is crucial for understanding the presence of organic and inorganic compounds and elements (Weiner, 2010). These properties play a significant role in determining water quality, with fluctuations influenced by geological and climatic conditions (Stark *et al*., 2000). The physical and chemical characteristics changes associated with the locations more than they are affected by the seasons changes, and the rivers are exposed during their course to the change related to the depth, flow rate, geology of the adjacent areas, nature of the bottom, salts concentration, turbidity and other factors change (Lee *et al*., 1993). Despite seasonal variations, the limnology of Iraqi water bodies has been extensively studied in recent decades such as Al-Azzawe *et al*.(2012); Hassan *et al*. (2014); Ala Allah *et al*. (2014); Al-Azawii *et al*. (2015); Salman *et al*.(2015); Nashaat *et al*.(2015); Rasheed *et al*.(2015); Salman *et al*. (2017); Mirza and Nashaat (2018); Alazawii *et al*. (2018); Abed and Nashaat (2018); Rhadi *et al*.(2018); Nashaat *et al*. (2019; 2020); Khalaf *et al*.(2021); Nashaat and Al-Bahathy (2021); Majeed *et al*.(2022); Abed *et al*. (2022) and Salman *et al*.(2023). This study aims to contribute to this body of knowledge by examining the upper sector of the Tigris River within Wasit Province, Southern Iraq.

MATERIALS AND METHODS

***Description of study sites*:** The study was carried out on upper sector of Tigris River, in Wasit Province, for the period from January to December 2022. Five sites were chosen ±10 Km apart from each other, divided along 1415 Km of the river (Fig. 1). The first site was located in the Suwayra District, about 135 Km far from north of Kut City, and it is about 55 Km far from Baghdad City to the south, at 3649841.938 N and 480129.668 E. The second site was located in Hafria District, about 110 Km far from north of Kut City and 60 Km south of Baghdad, at 3648752.026 N and 485518.798 E. The third site was located in Azizia District, about 85 Km far from south of Baghdad and about 90 Km far from north of Kut, at 3640797.777 N and 504988.921 E. The fourth site was located in Numaniyah District, about 45 Km far from north of the Kut City, and 193.7 Km far from south of Baghdad, at 3604272.479 N and 539294.603 E. Finally, the fifth site was located north of the Kut Barrage, at 3598020.410 N and 575265.550 E.

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All samples were taken from the surface layer at a depth of about 30-50 cm, with taking into account not to take samples from lentic water (Spellman,2020). Polyethylene locked containers with a capacity of 2,250 L was used, after being washed well with river water. Some characteristics were conducted at the study site directly, such as air and water temperature, electrical conductivity, total dissolved solids, and pH. The temperature was measured in the field by using a digital thermometer in all study sites by placing it in the shade until the reading is stable. While the temperature of water, electrical conductivity and dissolved solids were measured by using an Electrical Conductivity Meter of MARTINI Instruments (Spellman, 2015). The pH was measured by using HANNA (H19811) (Baird *et al*.,2017). Turbidity was measured with a Jenwaw Model 6035 turbidity meter.

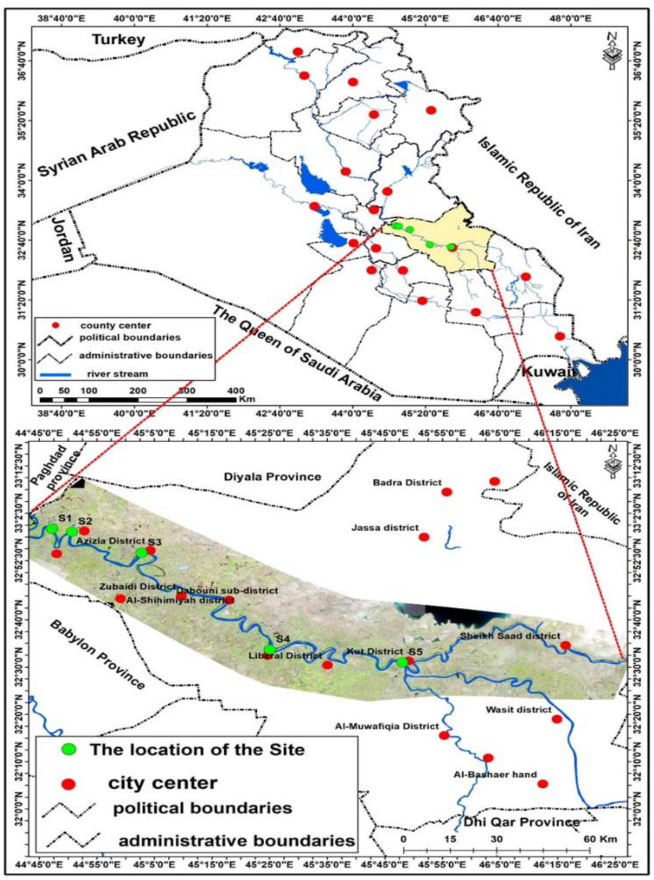

Figure 1. A map showing the study sites on upper sector of Tigris River within Wasit Province.

The dissolved oxygen and the Biological Oxygen Demaned were measured by Modification Azid Winkler's method (Spellman, 2020). The percentage oxygen saturation was calculated based on (EPA, 2012). Total suspended solids were measured according to the procedure mentioned by Spellman (2020). The total hardness, calcium and magnesium were measured according to standard methods (Baird *et al*., 2017). The sulphate ion was measured according to the procedure described by Brands and Tripke (1982). Phosphates were measured by using ascorbic acid, a Uv-spectrophotometer was used to measure nitrate as described by the standard method by Baird *et al*. (2017). Finally, the titration method of sulfuric acid was used to determine the total alkalinity as described by Spellman (2020).

Chlorine was measured according to Mohr's method (APHA, 2005). Sodium was measured by using a flame photometer (JEN Way PEP6), which is approved by the US Environmental Protection Agency (USHPF, 2012). The chemical oxygen demands was measured by using the Dichromate Reflex method described by APHA (1985).

Statistical analysis: Statistical analysis was performed using SAS software SAS-Statistical analysis system (2012), and to find the significant differences from the sites according to the results of the analysis of variance Duncan and this test was conducted at a significant level of 0.05.

RESULT AND DISCUSSION

The highest values of air temperatures were recorded during the summer, while the lowest values were recorded during the winter (Figure 2). This may be related to the climate of Iraq, which is characterized by hot, dry summers, cool, rainy winters (Al-Ansari, 2021). Through the results of the statistical analysis, it was found that there were no significant differences at $P > 0.05$ between the studied sites (Table 1).

The highest values of water temperature were recorded during the summer. While the lowest values were in winter (Figure 3), this may be due to the fact that the surface water temperature has a large seasonal variation and was positively associated with solar radiation (Jiang and Ni, 2018). Through the results of the statistical analysis, it was found that there were no significant differences at $P>0.05$ between the studied sites (Table 1).

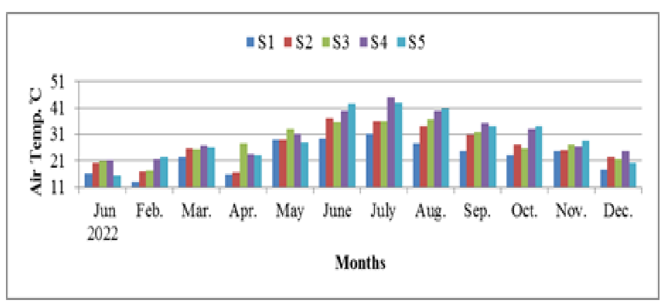

Figure 2. Monthly variation in air temperature values at the study sites.

Table 1. Averages, ranges, and standard error of physical and chemical parameters of Tigris River water during the study period.

Site Parameters	1	2	3	4	5	
Air Temp. °C	12.8-31 26.66.±1.741	16.5-37 26.66.±2.013	17.4-36.5 28.14.±1.853	21.1-45 30.68.±2.305	15.5-43 29.79.±2.618	LSD value
Water Temp. °C	6.8-22 12.59.±1.518	7.1-22.5 12.65.±1.566	6.7-22.5 12.88.±1.573	6.9-24 13.25.±1.639	6.4-24 13.61.±1.637	2.49 NS
Turbidity NTU	8.3-31.85 18.55.±2.263 b	7.11-35.63 17.94.±2.577 b	7.2-23.96 16.34.±1.556 b	14.9-38.22 23. ±1.962 ab	16.76-41.64 27.03.±2.315 a	8.021 *
EC µS/cm	880-1180 1058.3.±28.441	880-1250 1069.6.±33.89	890-1280 1080.±37.86	890-1280 1105.8.±34.47	960-1260 1119.2.±30.088	174.29 NS
Salinity ‰	0.595-0.75 0.68.±0.014	0.582-0.81 0.69.±0.019	0.569-0.81 0.68.±0.019	0.569-0.81 0.69.±0.019	0.614-0.81 0.70.±0.017	0.237 NS
pH	7.2-8.7 7.85.±0.121	7.3-8.3 7.80.±0.099	7.2-8.5 7.91.±0.112	7.2-8.6 7.95±0.145	7.1-8.5 7.95.±0.131	0.481 NS
DO mg/ L	8.5-13 11.±0.446 a	7.5-12.7 10.54±0.495 a	7.2-8.5 7.95.±0.112 b	8-12.5 10.21.±0.42 a	7.5-12.5 9.75.±0.441 ab	2.194 *
BOD_5 mg/ L	3.2-7.5 5.08.±0.476	3.5-7.3 5.17.±0.345	3.3-7.2 5.01.±0.381	2.9-6.8 4.54.±0.384	2-7.5 4.43.±0.472	0.905 NS
Oxygen Saturation %	73.59-132.45 102.56.±4.45 a	67.56-119.65 95.28.±4.70 ab	84.21-121.55 102.6.±3.73 a	74-118.7 97.03.±4.00 ab	63.34-118.7 88.75.±4.868 b	11.662 *
T.H mg/ L	360-760 503.33.±43.82	340-760 494.33.±37.06	320-760 498.33±41.15	320-720 485.±37.021	320-680 478.33.±34.769	41.68 NS
Ca^{+2} mg/L	100.2-200.4 142.43.±10.237	100.2-180.36 130.22.±7.609	100.2-200.4 132.06.±10.346	100.2-190.24 129.36.±9.251	100.2-190.24 132.05.±9.427	16.72 NS
Mg^{+2} mg/ L	14.59-98.3 42.09.±7.125	14.63-87.39 42.44.±5.259	16.9-99.58 47.54.±6.160	16.95-95 45.88.±6.606	16.9-93.5 42.85.±5.824	10.094 NS
SO_3^{+2} mg/ L	100-130 104.17.±2.87 c	120-200 152.5±7.19 bc	100-300 164.17.±15.64 ab	120-250 172.5.±11.87 ab	100-300 180.83.±19.36 a	46.31 *
$HCO_3^{=}$ mg/ L	120-190 162.92.±5.166	120-195 166.42.±7.673	140-200 163.75.±5.50	120-190 160.42.±6.497	130-200 165.42.±7.216	9.823 NS
TDS mg/L	0.47-0.59 0.52.±0.010	0.44-0.62 0.52.±0.017	0.44-0.64 0.53.±0.017	0.44-0.64 0.54.±0.016	0.48-0.63 0.54.±0.014	0.074 NS
NO_3 mg/L	0.508-1.97 1.21.±0.117	0.082-1.48 0.96.±0.117	0.196-1.79 0.93.±0.134	0.265-1.72 1.02.±0.133	0.398-1.8 1.19.±0.146	0.402 NS
PO_4^{-3} mg/L	0.03-0.048 0.035.±0.001	0.014-0.05 0.034.±0.002	0.01-0.046 0.034.±0.002	0.018-0.054 0.042.±0.002	0.009-0.064 0.045±0.009	0.015 NS
TSS mg/L	1-16 7 ± 1	1-16 6 ± 1	2-16 6 ± 1	1-18 7± 1	2-25 8±2	3 NS
Total Alkalinity mg/L	91.5-244 153.85.±14.159	91.5-213.5 157.37.±12.394	84.5-244 160.87±13.422	84.5-244 173.1.±13.792	120-244 175.96.±11.288	32.94 NS
Na mg/L	80.73-117.285 99.85.±5.255	80-124.173 102.81.±5.277	68.5-151.76 95.93.±7.992	82.7-151.7 100.68.±7.992	80.7-151.76 105.23.±7.722	12.68 NS
COD mg/L	7.87-18.45 13.11.±1.197	8.61-17.95 12.82.±0.845	8.11-17.71 13.14.±0.963	7.13-16.72 11.82.±0.925	7.13-18.45 12.41.±1.010	3.417 NS
CL mg/L	118.2-167.53 142.88.±7.428	118.2-216.81 146.99±9.587	98.55-216.81 141.24.±10.38	118.21-216.81 142.07.±11.21	118.21-216.81 146.17.±11.174	13.502 NS

* ($P \leq 0.05$, NS: Not significant.Averages with different letters within the same row are significantly different among themselves.

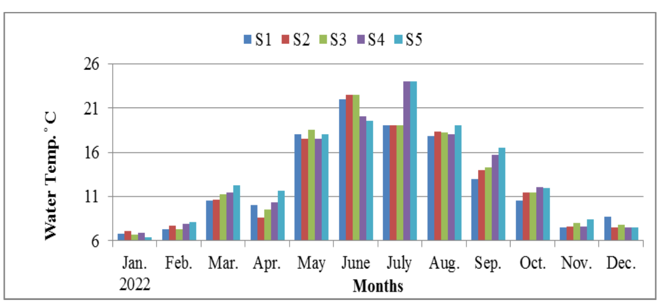

Figure 3. Monthly variation in water temperature values at the study sites.

The highest turbidity values of 41.64 NTU were recorded in May at site 5, while the lowest values of 7.2 NTU were recorded in December at site 3 (Table 1, Figure 4).

Through the results of the statistical analysis, it was found that there were no significant differences at $P \leq 0.05$ for sites 1, 2, and 3, which differed significantly with the rest of the sites (Table 1).

The highest turbidity values were recorded in the spring and summer, and their values decreased during the winter. The increase in turbidity during spring may be due to the increase in the bloom of phytoplankton, which leads to a decrease in

light penetration and a reduction of the photosynthetic zone below the water surface (Koven *et al.*, 2019). While the increase of turbidity values was recorded in the summer, it may be due to the increase in organic matter resulting from the decay and decomposition of plants in this season, or it may be due to the lack of plants that work to settlement the suspended materials, which leads to their rise (Mustafa, 2002). As for the low values of turbidity during winter, it may be due to the presence of large plants in the river, which have a major role in reducing the turbidity of the river.

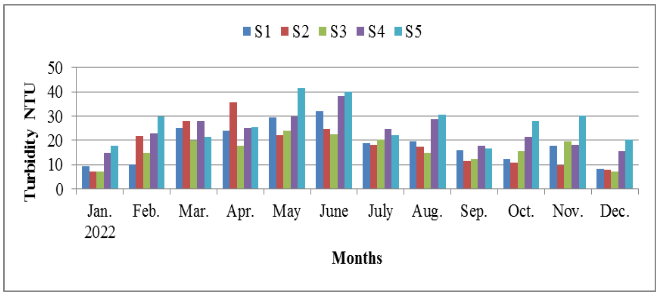

Figure 4. Monthly varation in water turbidity values at the study sites.

The highest electrical conductivity was ranged from 1280 µS/cm in site 3 and 4 in January, and the lowest value was 880 µS/cm in site 1 and 2, while salinity recorded the highest value during January in site 2, 3, 4, and 5, reaching 0.81 ‰, while the lowest value was recorded in April and June at site 3 and 4, respectively, as it reached 0.569 ‰ (Table 1, Figures 5 and 6).

Through the results of the statistical analysis of electrical conductivity and salinity, it was found that there were no significant differences at $P > 0.05$ between the studied sites, (Table 1).

The highest values of conductivity and salinity were recorded in the winter and spring and the lowest in the rest of the seasons (Fig. 5 and 6). This may be due to the rainfall in the winter and spring that caused runoff in the soil (Yasar Korkanc and Doram, 2019). The high values of both electrical conductivity and salinity may be due to the nature of the influents in the study area, as the values of electrical conductivity and salinity determine to the polluted areas because these sites have higher electrical conductivity than the unpolluted areas.

Montagna *et al.* (2013) and Hanrahan (2012) divided water bodies according to salinity values to less than 0.5 ‰ freshwater, but if it ranged from 0.5-5 ‰ Oligohaline, while if the value ranges from 5-18 ‰ Mesohaline, but if the value ranges from 18-30 ‰, Polyhaline, while if the value is 35 ‰, marine water. Therefore, according to the current study, Tigris water was 0.81‰ Oligohaline.

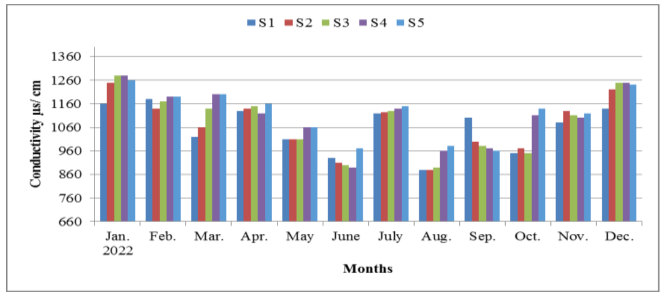

Figure 5. Monthly variation in electrical conductivity values at the study sites.

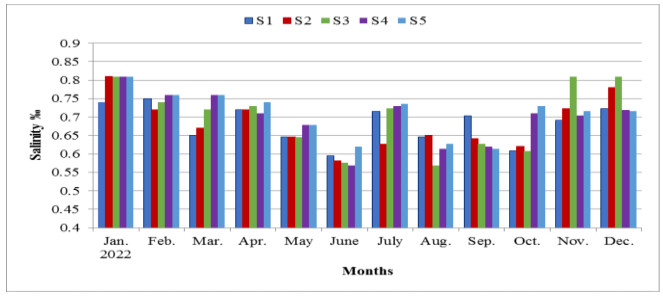

Figure 6. Monthly variation in salinity values at the study sites.

The highest values for total dissolved solid amounted to 0.64 mg/L during December in site 3 and 4, while the lowest values were recorded at 0.44 mg/L during August and June in site 2 and 4, respectively (Table 1 and Figure 7)

Through the results of the statistical analysis, it was found that there were no significant differences at $P>0.05$ between the studied sites, Table (1).

The highest values of total dissolved solid were recorded in winter and spring, also it was appeared a peak in the summer (Figure 7). This may be due to the low of discharge rate, which leads to a rapid increase in the deposition of mineral salts.

The results of the current study show that the TDS value of 0.64 mg/L was within the permissible limits (Omer, 2020).

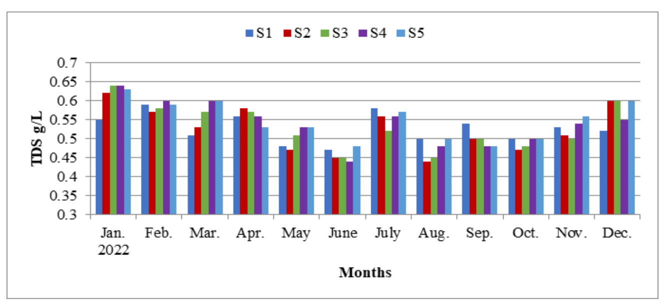

Figure 7. Monthly variation of TDS values in the study sites.

The current study recorded a maximum of pH was 8.7 on site 1 during May and a minimum of 7.1 during August on site 5 (Table 1 and Figure 8).
The results of the statistical analysis showed that there were no significant differences at P > 0.05 between the studied sites (Table 1).
The pH parameter recorded the highest values in the spring and autumn (Figure 8). As for the rise in pH values, it may be due to the large number of aquatic plants that carry out the process of photosynthesis, consuming large quantities of CO_2, leading to a rise in pH values (Al-Jizani, 2005). As for the decrease in the values in the summer, the reason may be due to the negative correlation between the pH and the temperature. By increasing pH values lead to increases of decomposing process of organic matter, and thus the release of CO_2 that its combine with water to form carbonic acid. In general, our results indicate that the pH values of Tigris River tend to be weak alkaline, due to the buffering property of Iraqi water bodies waters enriched with calcium bicarbonate ions.
The highest value of suspended solids was recorded in site 5, which amounted to 25 mg/L during November, and the lowest value was 1 mg/L in site 1 during August, site 2 in May and June, and site 4 in March, April, November, March, April and November. (Table 1 and Fig. 9).
Through the results of the statistical analysis, it was found that there were no significant differences at P>0.05 between the studied sites, Table 1.
The concentrations of total suspended solids increased during summer and the beginning of autumn (Fig. 9). This may be due to the fact that the dryness of the areas in summer leads to an increase in dust and dirt, and its transmission by winds from the roads and lands surrounding the river and its stagnation, causing an increase in turbidity and suspended solids (AL-Helaly, 2010).
The US Environmental Protection Agency (USEPA, 2002) divided water into three types depending on the value of the total suspended solids, as the concentration of less than 20 mg/L is pure, and water with total suspended solids value ranges from 20-80 mg/L is considered low turbidity, while values higher than 150 mg/L are considered turbid. Depending on the values of total suspended solids recorded during the current study, the waters of the Tigris River were considered low turbidity.

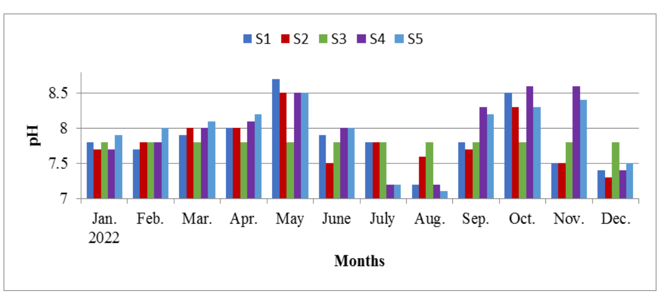

Figure 8. Monthly variation of pH values at the study sites.

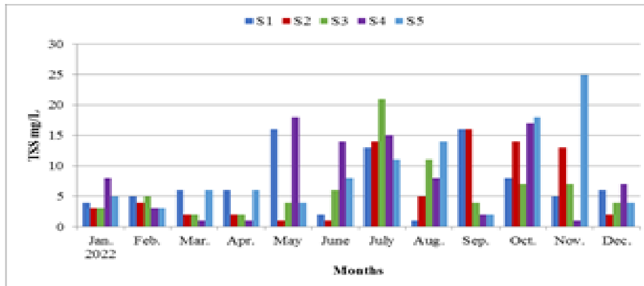

Figure 9. Monthly variation in the TSS values at the study sites.

The highest value of dissolved oxygen was recorded on site 1, which amounted to 13 mg / L during December, and the lowest value was 7.2 mg / L during August on site 3 (Table 1 and Fig. 10).
The highest values of the percentage of oxygen saturation were 132.45% on site 1 during December, and the lowest value of 63.34% was recorded in July on site 5 (Table 1 and Figure 11).
Through the results of the statistical analysis of dissolved oxygen, it was found that there were no significant differences at P≤0.05 between sites 1, 2, and 4, which differed significantly with the rest of the sites (Table 1). Also, the results of the statistical analysis of the percentage of oxygen saturation were recorded, that there were no significant differences at P≤0.05 between sites 1 and 3, which differed significantly from the rest of the studied sites, as well as the absence of significant differences at P≤0.05 between sites 2 and 4, which differed significantly from the rest of the studied sites (Table 1).
The highest values of dissolved oxygen and the percentage of oxygen saturation were recorded during winter and the lowest during summer in particular (Figures 10 and 11). This may be due to the reason for the existence of an inverse relationship between the water temperature and the percentage of dissolved oxygen, as the molecules of cold water carry more dissolved oxygen than the molecules of warm water because the molecules of cold water are less active (AL-Lami *et al.*, 2001).
Our result indicated that all sites within the international standard dissolved oxygen values (not less than 4 mg/L), which indicates its suitability for the aquatic environment. Dissolved oxygen in the environment of the Tigris River, which makes it suitable for the aquatic environment (. In addition, the percentage of oxygen saturation above 100% was recorded several times at all study sites throughout the year, which gives a true picture of the dissolved oxygen in the sampling area. Most aquatic ecosystem require dissolved oxygen in the range of 4-8 mg/L (Allan and Castill, 2007; Suthers and Rissik, 2009).

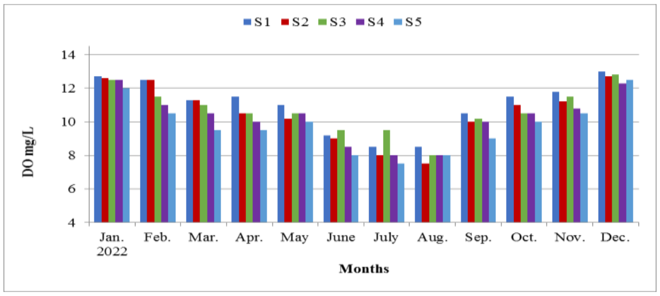

Figure 10. Monthly variation in dissolved oxygen values at the study sites.

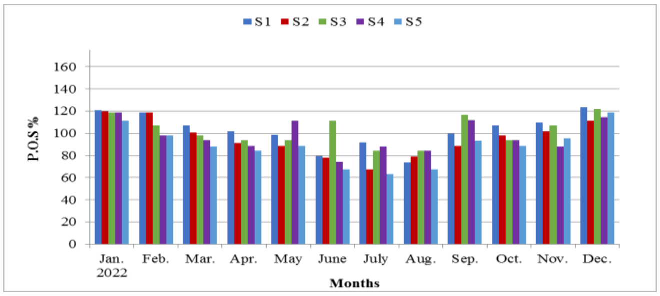

Figure 11. Monthly variation in the percentage of oxygen saturation values at the study sites.

The highest BOD_5 values of 7.5 mg/L were recorded during May and August on site 1, and the same was the case on site 5 during June. As for the lowest values, they were recorded on site 5 during February, where the value of the BOD_5 was 2 mg/L (Table 1and Figure 12).

Through the results of the statistical analysis, it was found that there were no significant differences between the sites studied at P>0.05 (Table 1).

The High values of the biological oxygen demands appeared during summer (Figure 12). This can be explained by the high temperature, as the value of the vital oxygen requirement is directly proportional to the temperature, as the high temperature leads to an increase in the activity of microorganisms that decompose organic matter (Moyel, 2010). As for the low values of the biological requirement for oxygen that were recorded in winter, it is due to the decrease in temperatures, which led to an increase in the oxygen concentration, or it may be due to the decrease in the decomposing organic matter process (Al-Taie, 2009).

The BOD_5 value is important for determining the level of pollution. If the value of river water is less than 1 mg/L, then the water is purer, but if the BOD_5 value ranges from 2-8 mg/L, the water is of moderately polluted. If the value exceeds 8 mg/L, the river is severely polluted (Li and Liu, 2019). The BOD_5 values in the current study did not reach critical values in most of the study times, which indicates that the waters of Tigris River are moderately polluted.

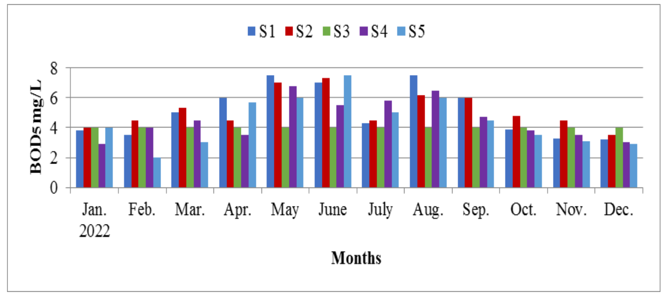

Figure 12. Monthly variation of BOD5 values in the study sites.

Figure 13 and Table 1 show the total hardness values at the study sites. On sites 1, 2, and 3, the highest value was recorded at 760 mg/L during January and February for both sites, respectively, and the lowest value was 320 mg/L for both site 3 and 5 during October.

Through the results of the statistical analysis, it was found that there were no significant differences at P>0.05 between the studied sites (Table 1).

The total hardness showed the highest recorded values in the winter season (Figure 13), and this may be due to the rains, as rain water causes an increase in the hardness of Iraqi water as a result of the calcareous nature of the Iraqi soil (Al-Janabi, 2011). The decrease in total hardness recorded in summer may be due to the dissolution of carbonates to compensate for the decrease in CO_2 values taken up by algae and phytoplankton (Lutz, 2000).

The water was classified into four types according to the total hardness, as the water that has a with less than 50 mg /L is considered non-hard water, while the value that ranges from 50-100 mg/L is medium hardness, and from 100-200 mg/L hard water and more than 200 mg/L are considered very hard water, therefore the Tigris River water is considered very hard water (Kevin, 1999).

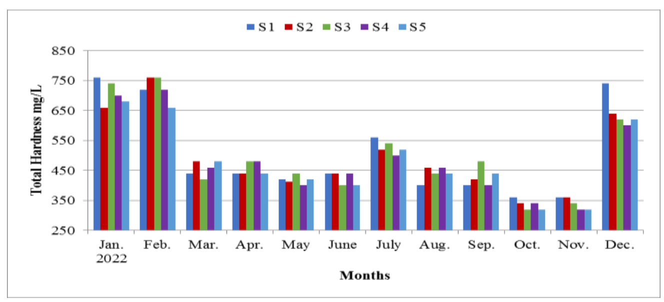

Figure 13. Monthly variation of the total hardness values at the study sites.

Calcium values showed a clear variation in the stations of the current study (Table 1 and Figure 14). In sites 1 and 3, the highest values were 200.4 mg/L during January and February, and the lowest were 100.2 mg/L, in site 1 during May, site 2 during March, site 3 during March, April, October and

November, and site 4 during April, May, October, and November, as for site 5 during April, May, October and November. The results of the statistical analysis showed that there were no significant differences at P>0.05 among the studied sites (Table 1).

The highest value of calcium ion was recorded in winter, and the lowest value was recorded in summer and spring (Figure 14). The reason may be due to the strong rain in Iraq in winter and because of the surface runoff of the soil that consists of limestone with rainwater to the river. As for the decrease in the value of calcium in spring and summer season, may be due to the increase in the numbers of phytoplankton and their use of calcium and magnesium as nutrients, as magnesium enters the composition of chlorophyll (Lind, 1979).

Fig. (15 and Table 1) show the magnesium values for the study sites. On site 3, the highest value was recorded at 99.58 mg/L during February, and the lowest value was 14.59 mg/L during October in the site 1.Through the results of the statistical analysis, it was found that there were no significant differences at P>0.05 between the studied sites (Table 1).

The values of magnesium concentrations recorded a clear variation. Its decrease in summer (Figure 15) that may be due to its consumption by plankton and plants present in the river water. As for the high values of magnesium concentrations in winter, it may be due to the decomposition of dead algae cells that contain chlorophyll, which introduces magnesium into its composition, or may be due to leakage magnesium from agricultural lands (Al-Ajrash, 2020).

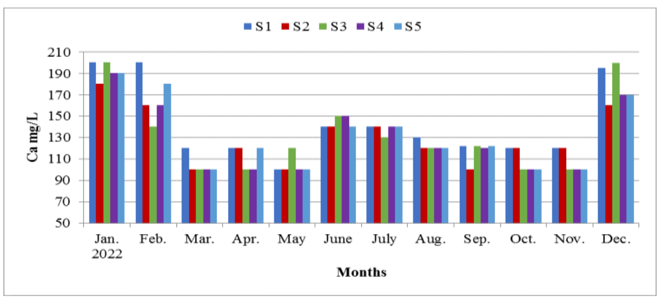

Figure 14. Monthly variation of calcium values at the study sites.

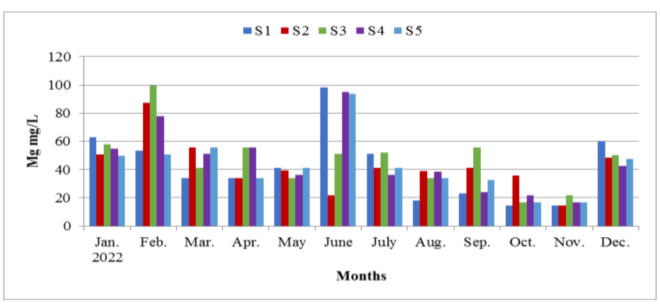

Figure 15. Monthly variation of magnesium values at the study sites.

Through the results of the current study, it was found that the value of calcium and magnesium ions amounting to 200.4 mg/L and 99.58 mg/L, respectively, falls within the permission limits of Tigris River for natural water of 200 mg/ L for calcium and 150 mg/ L for magnesium (EPA, 1999).

Fig. 16 and Table 1 show the sulphate values in the current study. On sites 3 and 5, the highest value was recorded at 300 mg/L during May, and the lowest value was 100mg/L on sites 1, 3 and 5. On site 1 during all months of the year except December and January, while on site 3 during February and site 5 during December, January and March.

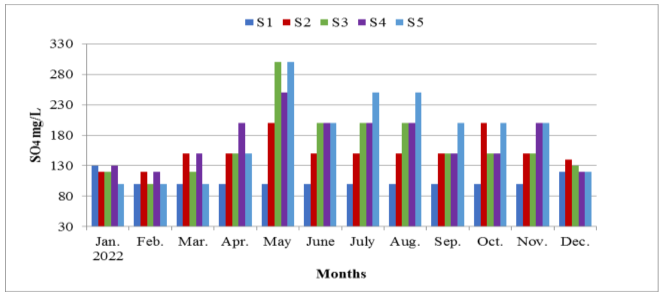

Figure 16. Monthly variation in sulphate values at study sites.

Through the results of the statistical analysis, it was found that there were no significant differences at P > 0.05 between sites 3 and 4, which differed significantly from the rest of the sites (Table 1).

It was found that the sulphate concentration increased during summer (Fig. 16), which may be due to the rise in human activities or due to the use of fertilizers containing sulphate to increase the agricultural crop during the agricultural season, as it moves to the river during its passage through those agricultural lands (Hassan *et al.*, 2005).

As for the decrease in the level of sulphats during winter, it may be due to the mitigation factor resulting from the rise in water levels and the increase in the discharge rate (Jazaa, 2009).

Sites 3 and 5 recorded the highest values of bicarbonate, which amounted to 200 mg/L during January for both sites, while the lowest values were recorded in sites 1, 2 and 4, which amounted to 120 mg/L during June in sites 1 and 2, while site 4 during December (Table 1 and Figure 17).

The results of the statistical analysis showed that there were no significant differences at P>0.05 between the studied sites (Table 1).

The highest values of bicarbonate were recorded in winter and the lowest values in summer (Figure 17). Carbon dioxide gas is associated with with bicarbonate and alkalinity, When the average temperature decreases, the CO_2 decreases and results in a decrease in photosynthesis in winter, in addition to the respiration of aquatic organisms and the lack of plants that consume gas, which raises the bicarbonate and alkalinity

(Taiwo, 2014). The low concentrations of bicarbonate during summer may be due to consumption of free carbon dioxide by primary producers and decomposition of bicarbonate (Hussein *et al*., 2000).
The current study showed that bicarbonate was within the permission normal limits according to the Iraqi and international specifications for water, which was 20-200 mg/L of calcium carbonate CaCO3 (APHA, 1985).

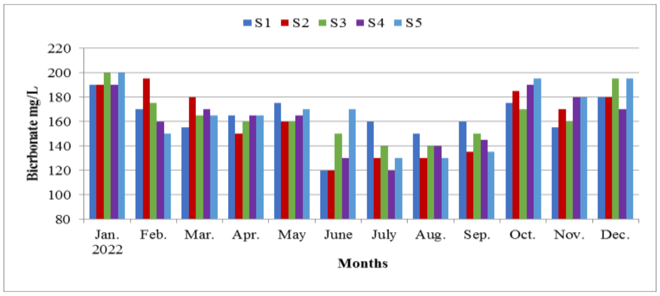

Figure 17. **Monthly variation in the values of $HCO_3^{=}$ (bicarbonate) at study sites**.

The current study recorded that the highest value of nitrate, 1.97 mg/L, was recorded in site 1 during February, and its lowest value was 0.082 mg/L, recorded during September in site 2 (Table 1 and Fig.18).
Through the results of the statistical analysis, it was found that there were no significant differences at P>0.05 between the studied sites (Table 1).
Nitrates recorded the highest values in winter and spring, and the lowest values was in summer and autumn (Fig. 18). It may be due to rainfall that washes nitrates from the soil into rivers (Gorski et al., 2019), while the low concentration of nitrates may be due to the biological uptake of nitrates during the growth period that occurs during this time (Drgon *et al.*, 2016).
Through the results of the current study, we find that the nitrate concentration is less than the permission limits according to the Water Resources Conservation System (2001) for nitrate concentrations in water sources of 15 mg/L.
Site 5 recorded the highest and lowest value for phosphate, as it recorded the highest value of 0.064 mg/L during June and the lowest value of 0.009 mg/l during May (Table 1 and Figure 19).
The results of the statistical analysis showed that there were no significant differences at P>0.05 between the studied sites (Table 1)
The highest values of phosphate were recorded throughout all months except May (Fig. 19). The reasons for the decrease in phosphate concentrations in summer are may be due to the increase in the number of plankton and aquatic plants that consume phosphate in large quantities (Al-Ajrash, 2020). The absorption of phosphorus is affecting by several factors, including temperature, pH and light intensity, which enters the water from various sources, including wastewater containing detergents and fertilizers phosphate that used to fertilize agricultural lands (Abboud, 2014).
In general, phosphate concentrations stayed low in Tigris River northern of Kut City. Moreover, it was slightly higher than the standard value (0.01 mg/L)(Allan and Castillo 2007; EPA, 2012). This may be attributed to its unaffected by human activities.

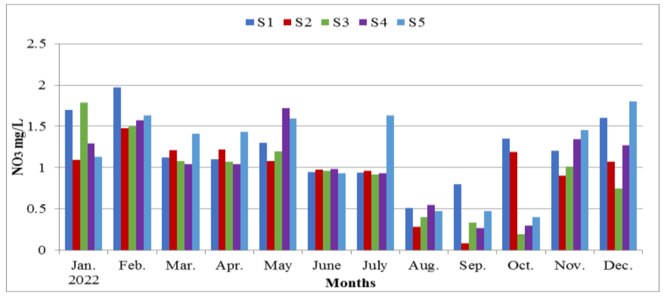

Figure 18. **Monthly variation in NO_3 values at study sites.**

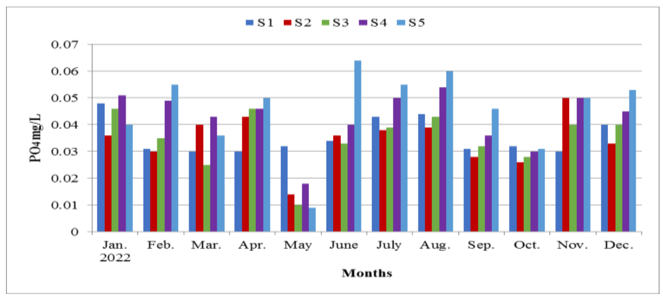

Figure 19. **Monthly variation of phosphate values at study sites.**

Sites 1, 3 and 5 recorded the highest value of total alkalinity was 244 mg/L during November for both sites, while Site 4 had the highest value of 244 mg/L during May, November. The lowest value was 84.5 mg/L in sites 3 and 4 during the month of August. (Table 1 and Figure 20).
Through the results of the statistical analysis, it was found that there were no significant differences at P>0.05 between the studied sites, Table (1).
The highest values of total alkalinity were recorded in spring and autumn, while the lowest were recorded in summer and winter (Figure 20). The reason for the high alkalinity may be due to the increase in the phytoplankton abundance. An increase in the density of phytoplankton means an increase in the photosynthesis process, as carbon dioxide gas is consumed in large quantities, leading to an increase in the total alkalinity (Retnaningdyah and Arisoesilaningsih, 2019).
While the reason for the decrease in total alkalinity in summer may be due to the consumption of free carbon dioxide by primary producers and the decomposition of bicarbonates (Hussein *et al*., 2000).

The results of the current study showed that the alkaline values amounted to 244 mg/L, which is higher than the normal limits allowed according to the Iraqi and international specifications for water, which were 20-200 mg /L. It was also noted that the Iraqi water has alkaline properties due to the presence of carbonate salts (Hussein, 2009).

The highest values of chemical oxygen demands were recorded in sites 1 and 5, which amounted to 18.45 mg/L, during May and June, respectively. As for the lowest values, they were recorded on site 4 during May, in which the values of the chemical oxygen demands were 16.72 mg / L (Table 1 and Figure 21).

Through the results of the statistical analysis, it was found that there were no significant differences between the sites studied at P>0.05 (Table 1).

The chemical oxygen demands values showed a decrease during winter only (Fig. 21), due to the amount of rain, which leads to mitigation, as well as the increase in the proportion of dissolved oxygen in the water as a result of the decrease in temperature (Golan, 2005). The increase in the content of the chemical oxygen demands indicates an increase for materials degradable (Aoun *et al.,* 2019).

The results of the current study showed that the value of COD amounted to 18.45 mg / L, which is within the permissible limits for the chemical oxygen demands, which is 100 mg / L (WHO, 2003). Therefore, the water of Tigris River was classified as polluted water to some extent.

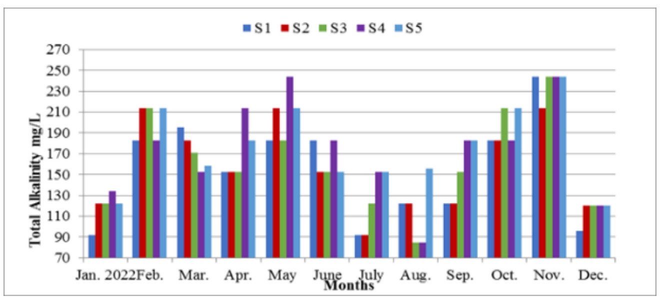

Figure 20. **Monthly variation in the total alkalinity values at study sites**.

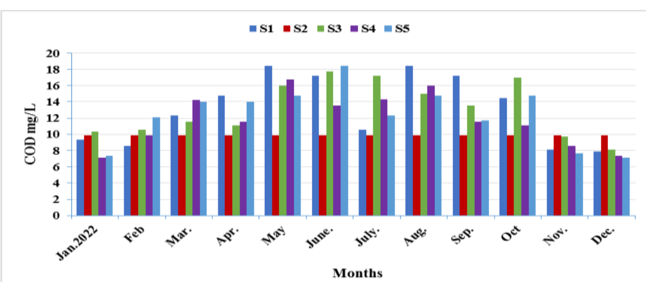

Figure 21. Monthly variation in the chemical oxygen demand values in study sites.

The highest chlorine values were recorded in sites 2, 3, 4 and 5, which amounted to 216.81 mg/L in site 2 during September, site 3 during April, site 4 during April and September, and site 5 during April and July. As for the lowest values, they were recorded in site 3 during November, and amounted to 98.55 (Table 1 and Fig. 22).

Through the results of the statistical analysis, it was found that there were no significant differences between the studied sites at P>0.05 (Table 1).

It was showed an increase in chlorine concentrations in spring and autumn (Fig. 22), perhaps due to a decrease in water discharges or mmay be due to an increase in sewage into the river because the water is laden with waste and rich with those ions (Al-Amiri, 2009). As for the reason for its decrease in summer, the reason may be due to the increase in water discharge rates during this month (Razouki, 2021). As for its low concentration during winter, it may be due to low evaporation rates and suitable temperatures, as well as low salinity, which led to low chloride concentrations in the water.. Through the results of the current study, the highest value of chlorine was 216.81 mg/ L, which is within the permissible standards of 250 mg / L for the World Health Organization (WHO, 2017).

The highest sodium ion values were recorded on sites 3, 4 and 5, which amounted to 151.76 mg/L on sites 3 and 5 during April and site 4 during April and September. As for the lowest values, they were recorded on site 3, with a value of 68.2 mg/L during October and November, Table 1 and Figure 23.

Through the results of the statistical analysis, it was found that there were no significant differences between the studied sites at P > 0.05 (Table 1).

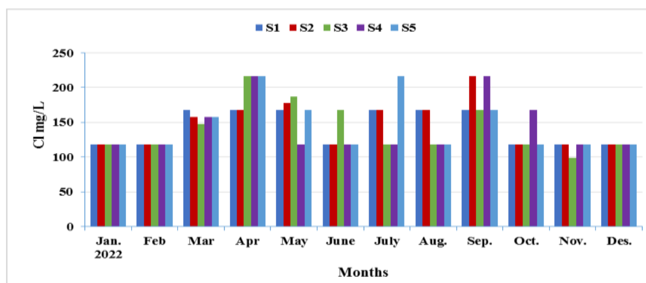

Figure 22. Monthly changes in chlorine ion values at study sites.

Sodium ion concentrations increased in spring and summer season, as the study records a significant increase in the sodium ion values, especially in April (Figcure 23), and this may be due to the gradual rise in temperature in April and to the increase in electrical conductivity values that are related to salinity (Salman, 2006).

The concentration of sodium in freshwater ranged from 1-10 mg/L and the level specified within the global health specifications amounted to 200 mg/L (Chapman, 1992), so

the values of the current study are within the permission limits of 151 mg/L.

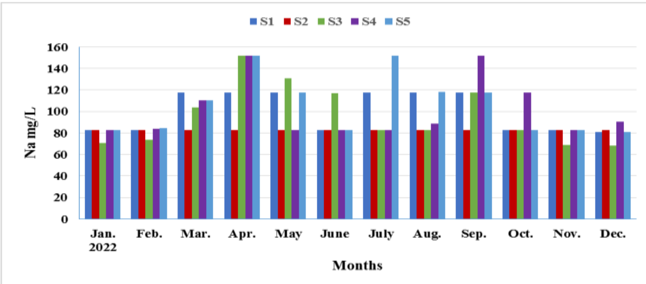

Figure 23. Monthly variation in sodium ion values at study sites.

***Conclusion*:** This study provides a comprehensive analysis of the physicochemical parameters of the Tigris River in Wasit Province. The findings contribute valuable information for understanding water quality dynamics in this region. Continuous monitoring and further research are recommended to assess long-term trends and potential impacts on aquatic ecosystems.

Authors contributions statement: Muhanned R. Nashaat: Conceived the idea, designed the study and reviewed the manuscript; Shaima J. H. Idrees: Collected the data and wrote the manuscript; Jameel S. AL-Sariy: Assisted in reviewing and editing the manuscript; Muhanned R. Nashaat: Assisted in proofreading; Shaima J. H. Idrees was encouraged by Muhanned R. Nashaat and Jameel S. AL-Sariy to research [a specific aspect], and these two men oversaw the research's results. Each author contributed to the final manuscript and discussed the findings.

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Ethical statement: There is original research work and not yet published elsewhere

Availability of data and material: Data will be available on realistic request.

Code Availability: Not applicables

Consent for publication: All authors are giving the consent to publish this research article in JGIAS

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